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AN EXPERIMENTAL STUDY OF THE REACTIONS OF THE HORNED LIZARD, PHRYNOSOMA MODESTUM GIR., A REPTILE OF THE SEMI-DESERT.¹

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I. INTRODUCTION.

The species of *Phrynosoma* which is the subject of these observations is one of the smaller and less conspicuous members of the genus, and is one of the commoner "horned toads" in New Mexico, which lies at the center of its rather restricted range (Ditmars, '08). This species, *Phrynosoma modestum* Gir. (Girard '53) has been confused to a certain extent in the literature (Herrick, *et al.*, '99) with another small member of the genus, *Phrynosoma platyrhinos* Gir. (Girard, '53) which extends into New Mexico from the northwest, but a reference to the original descriptions differentiates very clearly between the two groups.

1. General Habits.

Near Albuquerque, where the individuals observed were taken, the species is widely distributed over the sparsely vegetated "mesa" (Watson, '12) or clinoplane region varying in altitude from 1,500 to 2,200 meters and having a rainfall of approximately 30 cm. annually. Bailey ('13) gives the distribution of this animal as the Lower and Upper Sonoran Zones in New Mexico. In the valley of the Rio Grande, just below the "mesa" region, and in

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the Sandia Mountains bordering on the upper side the very different *Phrynosoma douglasii ornatissimum* prevails. This species is also found on the mesa but in much smaller numbers, and is said by Bailey (*l.c.*) to occur in the Upper Sonoran Zone. The whole region under consideration is given in his map as the Upper Sonoran Zone, with the exception of the Sandia Mountains, which included the Transition and Canadian Zones, in both of which the above variety of *P. douglasii* is found. Both mountains and valley are considerably damper than the mesa, the former on account of the greater annual rainfall, and the latter on account of the proximity of the Rio Grande and the high water table (10 cm. to 5 m. from the surface of the soil (Nelson, *et al.*, '14)). The distribution of these species seems to depend, not primarily on air temperature or on the factors which define the Life Zones of Merriam, although the upper limit of *P. modestum* approximately coincides with the upper border of the Upper Sonoran Zone, but upon factors which are in agreement in the river valley and the mountain range. Ants, the principal natural food of *P. modestum*, are more abundant in the mesa region, but this may be merely a secondary factor as far as distribution is concerned, as the animals eat and thrive well upon small beetles, plant bugs, grasshoppers, etc. The distribution of the species coincides with the grassy step formation of Watson ('12) falling in Shelford's ('13a) third division, *formations of savannas and grasslands*.

In captivity, it was observed that the lizards ate readily any living and moving insect or other animal of sufficiently small size. The animals have been observed even to ingest lead shot kept in motion by being rolled down an inclined plane, and occasionally snap at moving sand grains. The attempts of a medium-sized *P. douglasii* to swallow an earthworm of three times its own length were rather interesting. The lizard braced itself by means of its legs and attempted to pull the worm apart, but finally succeeded in swallowing it whole, shaking it in the process much after the manner of a dog shaking a snake. Large woolly caterpillars, grasshoppers of considerable size and other seemingly difficult objects were swallowed with comparative ease. The animals were never observed in the act of drinking and evidently obtained the amount of moisture required with the food.

Phrynosoma modestum is not, essentially, a desert and heat-loving species, although it seems more tolerant of desert conditions than *P. douglasii*. It appears in the greatest abundance in the early summer months, and during the early autumnal rainy season when the aërial temperature does not exceed 32° C., and when the temperature of the substratum in the sunlight is not over 38°. During these periods the animals actively move about all day, remaining during the night in protected nooks under bushes or in the burrows of other small animals, or occasionally buried in the loose soil. When the daily maximum temperature becomes greater the period of activity begins earlier in the morning and is terminated toward noon, when the temperature rises. During the heated part of the day the lizard is at rest, nearly, if not quite, covered by the loose soil or sand. The method by which this position is reached is very characteristic. The snout is directed downward and moved from side to side, the body extremely flattened, while the legs take part in a rapid horizontally clawing movement. The net result of this series of motions is to cover the animal with the loose soil, the depth varying according to the character of the soil, the individual, etc. When the temperature is high, sunlight is avoided and burrowing is more likely to take place in the shade of vegetation, a bank of soil or a rock. Other lizards have been observed to burrow in like manner as a means of escape from enemies.

2. Color and Color Changes.

The color of the animal generally resembles rather closely the color of the substratum, but this is not always the case. In general, individuals observed after a rain are darker in color (the soil is also darker) and very much lighter on a hot dry day. Experiments have shown, in the case of *P. douglasii*, that a rise in temperature, darkness or an increase in the evaporating power of the air causes a centripetal migration of the melanophoric pigment, while the opposite conditions induce a corresponding movement. Within the limits of the changes occurring in the habitat, the variation in the evaporating power of the air is the most potent of the above factors of color change. No direct connection between the color of the animal and that of the substratum has been confirmed experimentally.

3. *Behavior in Captivity.*

In captivity they are rather inactive, except when living food animals are introduced into the cage, when they may become very active, or when otherwise disturbed. They spend a great deal of time with the belly flattened to the ground, with the head lowered and the eyes closed. When the sun is not shining directly on the cage the majority of the animals are oriented toward the source of light (*e. g.*, a window) and often climb up on the side of the cage toward the light. On a cool morning they often orient themselves with respect to the sun so that the surface of the back is as nearly as possible perpendicular to the path of the rays. This is accomplished by tilting the body sidewise. When the air temperature is in the neighborhood of 30° or above direct sunlight is avoided, and the animals are active only when the cage is shaded. This is not in line with reported field observations on *Phrynosoma*, most of which seem to be based on the true desert species.

The horned lizards used for the following experiments were taken near the lower edge of the "mesa" (altitude 1,700 m.) just east of the city of Albuquerque, New Mexico, and near the campus of the University of New Mexico, about June 10, and shipped by express to the University of Illinois. They were kept, during the experiments, in two lots, one (cage No. 1) in a cage on the floor of a northeast second-floor room of the vivarium building, where the sunlight reached the cage but a few hours each forenoon. The evaporation in this cage, as measured with the Livingston porous cup atmometer averaged .5 c.c. per hour or 12 c.c. in 24 hours. The other lot was kept in a similar cage in the ground-floor greenhouse, where they were subjected to the direct rays of the sun until 2 P.M. The evaporation was here .8 c.c. per hour. The animals were fed black ants the greater part of the time, with occasional feedings of miscellaneous insects from net sweepings of vegetation near the building.

II. EXPERIMENTAL RESULTS.

1. *Air Humidity Gradients. (Evaporation Varied by Differences in Air Humidity.)*

A large number of experiments (120) were performed with the object of determining the optimum air evaporation and the

reactions of the animals to air of different evaporating powers. The evaporation gradients were established by varying the humidity, the temperature and the rate of flow of the air to which the animals were subjected. The apparatus used in the gradient experiments was essentially the apparatus described by Shelford and Deere (1913) and Shelford ('14a) with the following modifications. The source of the air was the compressed air system of the University of Illinois. The measurement of the flow of the air was made more accurate by the insertion in the supply line of delicate draft gages described by Hamilton ('17). The gradient cages used in this series of experiments were also larger ($45 \times 8 \times 5$ cm.) to accommodate the larger animals, and the floors were covered with a layer of sand 1 cm. in thickness.

The experiments ordinarily covered each a period of twenty minutes, each space on the recording blank representing ten seconds, as indicated in the accompanying Chart I. The figures at the top of each column represent, respectively, the relative humidity, computed from readings of standard wet and dry bulb thermometers, and the evaporation per twenty-minute period, measured with porous cup atmometers, of the air supplied the corresponding third of the gradient cage. In the graphically recorded experiments an animal was placed in the cage, generally in the center section, and its movements recorded by means of tracings. In the statistically recorded experiments ten individuals were distributed through the cage and records of their positions made at the indicated intervals. Experiments designated by the same number were performed consecutively and with the *same* animal or group of animals. Otherwise the numbering is entirely arbitrary. For a more complete account of the method of recording, etc., see the explanation of Chart I.

In Experiments 12, 13 (Table I.) ten individuals were placed in the gradient cage and readings as to position were taken every thirty seconds, the final results being expressed in percentage figures. Experiment 12 was performed with individuals from Cage No. 1, in which the temperature varied between 24° and 35° , while those used in experiment 13 were from Cage No. 2, where the temperature rose to 40° during the warmer parts of the day. There was no marked difference in the behavior of the two

TABLE I.

SHOWING THE REACTIONS OF *Phrynosoma* IN GRADIENTS OF AIR HUMIDITY.

The method of procedure here was the same as that pursued in the experiments illustrated in Chart I., except that ten individuals were used in each experiment and numerical readings were taken at half-minute intervals. The summation of the results is indicated in numbers and in percentages at the foot of the columns. See explanation accompanying Chart I., and page 102 for discussion.

Minutes.	Experiment 12.			Experiment 13.			Experiment 15.		
	Humidity.			Humidity.			Humidity.		
	98%.	57%.	6%.	6%.	57%.	98%.	93%.	52%.	5%.
	0.3.	0.8.	2.0.	2.0.	0.8.	0.3.	0.2.	0.5.	1.8.
1	3	3	4	3	3	4	3	4	3
	4	2	4	2	5	3	1	6	3
	3	4	3	1	7	2	2	4	4
2	4	3	3	1	7	2	2	5	3
	4	4	2	2	7	1	3	5	2
3	5	4	1	4	5	1	3	5	2
	5	4	1	3	3	4	3	4	3
4	5	3	2	1	3	6	3	5	2
	5	4	1	2	4	4	2	5	3
5	4	6	0	2	2	6	2	6	2
	4	6	0	4	2	4	2	6	2
6	3	6	1	3	3	4	4	5	1
	5	4	1	1	4	5	4	5	1
7	5	4	1	2	3	5	3	5	2
	5	5	0	2	3	5	4	4	2
8	5	4	1	1	3	6	4	4	2
	5	4	1	3	2	5	1	5	4
9	4	5	1	3	5	2	3	5	2
	2	5	3	2	5	3	1	6	3
10	6	2	2	2	3	5	1	5	4
	4	3	3	4	4	2	0	5	5
11	4	4	2	4	4	2	1	5	4
	5	4	1	2	4	4	1	5	4
12	5	4	1	3	4	3	1	4	5
	3	5	2	5	2	3	0	5	5
13	3	5	2	3	3	4	3	3	4
	3	4	3	1	4	5	1	7	2
14	4	4	2	4	4	2	1	8	1
	3	5	2	4	3	3	2	8	0
15	4	4	2	3	2	5	1	8	1
	5	4	1	2	5	3	2	8	0
16	5	3	2	1	4	5	1	8	1
	6	3	1	3	2	5	2	6	2
17	5	2	3	2	4	4	1	8	1
	4	3	3	2	5	3	1	8	1
18	3	6	1	4	5	1	1	7	2
	5	4	1	1	7	2	0	9	1
19	5	2	3	0	7	3	3	7	0
	5	4	1	2	5	3	2	7	1
20	5	3	2	2	5	3	3	7	0
	172	157	71	97	160	143	89	218	93
	43%	39%	18%	24%	40%	36%	22%	54%	24%

groups in this or in other experiments. In both cases the driest air was avoided, and the greatest number were found in the central portion of the cage, where the evaporation was .84 during a twenty-minute period. Many other similar experiments gave similar results.

Experiment 15.—This experiment did not show as much difference between the extremes but showed a great percentage in favor of the central section of the gradient cage in which the evaporation was much lower than in the preceding experiment (.5).

Summary of Air Humidity Gradient Experiments.

The animals ordinarily avoid air of excessive evaporating power, or, if they remain in such air, are stimulated in such a way that attempts to escape are made, or are stimulated to burrowing or digging activities. The net result of either reaction, if successful, is an escape from the unfavorable environment. As nearly as could be determined from the data at hand the optimum evaporation for the average animal lies between .5 c.c. and 1.0 c.c. expressed as the evaporimeter reading for a twenty-minute experimental period. There is a considerable variation in individual behavior and that of any individual will vary from time to time, due, presumably to changes in physiological condition. The normal evaporating power of the air in the natural habitat during the months of April and May varies from .15 c.c. twenty-four hour average on a rainy and cloudy day, to 1.0 c.c., on a bright clear day when the maximum temperature is in the neighborhood of 30°. Although day and night observations have not been made separately it is evident that the average evaporation for the daylight hours would be somewhat higher than the figures just given.

Animals kept for a long time in abnormally dry atmospheric conditions evidence a marked degree of uneasiness, indulge in many spasmodic movements, and finally either burrow or apply the body closely to the substratum. They are, however, able to endure long exposure to dry air without death. A 2.5 gram animal was exposed to a constant current of air with an evaporation of 2.4 c.c per twenty-minute period for a week before death took place. Death in this case was also probably largely due to

starvation, as it was difficult to induce the animal to take food under the conditions of the experiment. The weight in this time was reduced to 2 grams.

The broad limits of the evaporation optimum make it rather unlikely that this factor is the principal one in determining the local distribution of the species. It would not be expected that this would be the case in a reptile from such a habitat, where the evaporating power of the air is subject to such great variations in the course of twenty-four hours. Reptiles, also, are, in general, especially adapted to withstand a considerable amount of drouth, the water loss through the integument being very slight and that through the feces and urine almost negligible, as compared to the similar losses of other animals.

2. *Air Temperature Gradients. (Evaporation Varied by Differences in Air Temperature.)*

Experiments with an air temperature gradient were carried out in the same apparatus as the previous experiments, the air passing through the cage being heated or cooled by passing through coils immersed in water of high or low temperature. The air came directly from the storage tank and was unmodified except as above noted and flowed at the same rate as in the humidity experiments. The experiments (34, *a*, *b*, *c*) summarized in Table II. together with the many others performed in the same manner show the optimum to be between 33° and 38° when the substratum is not cooled, *i. e.*, when the temperature of the substratum varies approximately with the air. When the substratum is cooled the optimum more closely approaches 30°, which corresponds, under the conditions of the experiment, to air with an evaporation of 1.0 c.c. for the experimental period. Both humidity and temperature gradients are essentially evaporation gradients and optima are most conveniently expressed in terms of evaporation (Shelford '13*b*).

TABLE II.

EXPERIMENT 34. SHOWING THE REACTIONS OF *Phrynosoma* IN AN AIR TEMPERATURE GRADIENT.

The temperatures of the thirds of the cage are in each case indicated at the top of the column. Readings were taken at one-minute intervals. For discussion see page 105.

Minutes.	Experiment 34a.			Experiment 34b.			Experiment 34c. ¹		
	Temperature.			Temperature.			Temperature.		
	29°.	33°.	38°.	38°.	33°.	29°.	37°.	29°.	27°.
1	3	3	4	3	4	3	3	2	5
2	4	2	4	3	5	2	3	2	5
3	4	2	4	3	6	1	3	2	5
4	4	2	4	4	4	2	3	4	3
5	3	2	5	4	4	2	4	4	2
6	3	2	5	4	5	1	4	3	3
7	3	4	3	4	5	1	4	3	3
8	3	4	3	4	5	1	4	3	3
9	3	4	3	4	5	1	5	3	2
10	3	4	3	4	5	1	5	3	2
11	3	4	3	4	5	1	5	3	2
12	4	3	3	4	5	1	4	5	1
13	2	4	4	4	5	1	4	5	1
14	2	4	4	4	4	2	4	6	0
15	2	4	4	3	5	2	4	5	1
16	2	2	4	3	5	2	4	5	1
17	2	4	4	3	5	2	4	5	0
18	2	3	5	4	5	1	5	5	0
19	2	3	5	4	5	1	6	4	0
20	2	3	5	5	4	1	6	4	1
21	2	3	5	5	4	1	6	4	0
22	1	5	4	5	4	1	6	4	0
23	1	5	4	4	5	1	7	3	0
24	1	5	4	4	5	1	7	3	0
25	1	5	4	3	6	1	7	3	0
26	1	4	5	3	6	1	7	3	0
27	1	4	5	3	6	1	6	3	1
28	1	4	5	3	6	1	6	3	1
29	1	4	5	3	6	1	6	4	0
30	1	4	5	6	3	1	6	4	0
31	1	4	5	6	3	1	6	4	0
32	2	2	6	5	4	1	6	4	0
33	1	2	7	5	4	1	6	4	0
34	1	4	5	5	4	1	6	4	0
35	1	4	5	6	3	1	5	5	0
36	1	4	5	5	4	1	5	4	1
37	1	4	5	5	4	1	5	4	1
38	1	4	5	5	4	1	5	4	1
39	1	4	5	6	3	1	4	5	1
40	1	4	5	5	4	1	4	5	1
	78 20%	144 36%	178 44%	167 42%	184 46%	49 12%	200 50%	153 38%	47 12%

¹ Substratum cooled to 20°.

3. *Substratum Temperature Gradient.*

The gradient cage was placed in a water bath so arranged that hot water flowed into the latter at one end and cold water at the other, the water being directed backward and forward beneath the cage so as to produce a gradient in the temperature of the substratum. This experiment was conducted with still air in the cage, *i. e.*, with air of approximately the same temperature as the substratum and consequently varying in evaporating power, and with air of a uniform temperature and evaporating power flowing across the gradient. The results of the two types of experiment checked very closely, indicating that the temperature of the substratum is the dominant controlling factor under these conditions. Both show an optimum substratum temperature of 35° to 40°. In general the animals which had been kept at the higher temperature, *i. e.*, in cage No. 2, oriented themselves in the gradient more quickly than those kept at the lower temperature (Experiments 26, 27 *a, b*, Table III.). When the animals gathered in the region of the optimum temperature an increase or decrease of the temperature of the gradient caused a corresponding movement of all the animals, which were repeatedly driven from end to end of the cage in this manner. The lizards often burrowed at or near the upper limit of the optimum region. They also often burrowed when the temperature was reduced as low as 20°.

When the animals were placed in a cage the substratum of which was gradually heated, rapid movements, interspersed with digging reactions began at 35°, and as the temperature approached 40°, all animals attempted to burrow. However, under experimental conditions, it was impossible to heat the substratum without having the lower layers of the soil at least as hot as the top, and the animals did not complete the burrowing reaction, but again moved about the cage rapidly. Above 40°, evidences of extreme discomfort, such as wide-open mouth, spasmodic movements, etc., were evidenced.

When animals in a sand-bottom cage were subjected to a continuous blast of air of increasing temperature from above, so as to heat the surface of the soil without greatly increasing the temperature of the lower layers of the soil, they became very

TABLE III.

SHOWING THE REACTIONS OF *Phrynosoma* IN A GRADIENT OF TEMPERATURE OF THE SUBSTRATUM.

Temperatures are indicated at the tops of columns. Readings were taken at intervals of one minute. In Experiment 27 the figures in italics indicate burrowing on the part of the number of individuals so designated. For discussion see page 107.

Minutes.	Experiment 26.			Experiment 27.		
	Temperature.			Temperature.		
	19°.	39°.	43°.	25°.	40°.	52°.
1	3	4	3	2	6	2
2	1	5	4	1 1	8	0
3	1	4	5	1 1	8	0
4	1	3	6	1	8	1
5	0	4	6	1	8	1
6	0	4	6	1	8	1
7	1	4	5	1	8	1
8	1	5	4	1	9	0
9	2	5	3	1	9	0
10	3	4	3	1	9	0
11	4	3	3	1	1 8	0
12	4	3	3	1	1 8	0
13	2	5	3	Redistributed		
14	1	5	4	21°	36°	46°
15	1	5	4	4	2	4
16	1	5	4	4	3	3
17	1	5	4	3	4	3
18	1	5	4	3	4	3
19	1	5	4	3	5	2
20	1	6	3	3	5	2
21	2	5	3	3	6	1
22	0	7	3	1	9	0
23	1	5	4	0	9 1	0
24	1	5	4	0	9 1	0
25	0	5	5	0	9 1	0
26	0	5	5			
27	0	5	5			
28	1	4	5			
29	0	5	5			
30	0	5	5			
31	0	5	5			
32	0	4	6			
33	0	5	5			
34	0	3	7			
35	0	4	6			
36	0	3	7			
37	0	3	7			
38	0	4	6			
39	1	3	6			
40	0	4	6			

restless as the temperature of the soil approached 40°. Most of the animals burrowed, or at least flattened their bodies close to the substratum as the surface temperature reached two or three

degrees above this. Unfortunately, in the apparatus available a higher air blast temperature than 43° could not be obtained.

The reaction to the temperature of the substratum, independent of the temperature and rate of movement of the air above and consequently independent of the evaporating power is the most definite and well defined response noted in the series, much more so than that in the air temperature and humidity experiments and must, therefore, represent an important factor in the daily and seasonal life of the animals. It is probable that this, and not the evaporating power of the air furnishes the most important direct stimulus determining the distribution and daily movements of the species. The surface of the soil in the Rio Grande valley region is cooler than that in the mesa habitat on account of its greater moisture content, and that in the mountains is cooler for this reason and also on account of the climatic variations due to higher altitude. The rise of temperature during the day stimulates the animal to burrow as a means of escaping the excessive heat. At least the surface temperature is of very great importance, as shown by the exceedingly consistent and regular behavior of the animals when this feature of their environment is varied. Unfortunately, but a single specimen of *P. douglasii* was available at the time the preceding experiments were conducted, and this one was taken at the same place as those of the more abundant species, *i. e.*, on the mesa. It would be of great profit to repeat this experiment with individuals of various species taken in entirely different habitats.

III. CONCLUSIONS.

1. The optimum evaporation rate of air for *Phrynosoma modestum* lies between 1.5 and 3 c.c. per hour, as measured by a standard atmometer. This is approximately the average evaporation rate of outdoor air in the natural habitat of the species, in sunlight, with a light breeze and a temperature of 30° . The reaction of the animals to a humidity gradient is not definite unless the gradient be a steep one. Daily variation in the habitat of the species is rather large.

2. The reaction to an air temperature gradient is more definite than the preceding. As temperature varies, the evaporating

power of the air also varies, and thus we get an evaporation gradient plus a temperature gradient, so that the gradient under these conditions is a double one. The optimum temperature is in the neighborhood of 30° when the humidity and rate of flow of the air is such as to produce an evaporation of 3 c.c. per hour, as measured by a standard atmometer.

3. Air humidity, air temperature and air current gradients are all essentially evaporation gradients, and the optimum in each case is a function of the evaporating power of the air.

4. The most definite and clear cut reaction in a gradient shown in this series of experiments is that in the substratum temperature gradient. This reaction is, to a great degree, at least, independent of accompanying differences in air temperature and humidity, or at least, the effect of these variations is overshadowed by the response to the gradient in substratum temperature. The optimum substratum temperature is rather definite—between 36° and 40° , and at the upper limit a very definite reaction (burrowing) takes place. This optimum is correlated with the other optima given above, in that the substratum temperature, under the conditions given in paragraph 1, is usually from five to ten degrees above the temperature of the air. Soil temperature (surface) is evidently of very great importance in determining details of seasonal and daily life, having as well its accompanying effect on the distribution of the species.

4. It is dangerous to ascribe to any one factor or group of factors the supreme rôle in determining the seasonal or general distribution of a species. The factors are certainly not the same for all species even in the same environment and before definite conclusions can be drawn a careful analysis of the habitat must be made, and experimental data must be obtained as to the reaction of the animals in gradients involving the factors capable of variation.

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CHART I. Showing the reactions of *Phrynosoma* in gradients of the evaporating power of air. In the experiments illustrated this gradient was established by varying the humidity of the air with which the animals came into contact. The manner in which the gradient was established and the records made was as follows: A rectangular cage approximately 50 cm. \times 10 cm. and 5 cm. deep was so arranged that currents of air from different sources could be directed across different sections of the cage. The openings were so arranged that the air passing across a given third of the cage was of uniform character throughout the experimental period, while that in each third differed as to humidity, but in no other way from that in the other sections of the cage. The animal could pass freely from one part of the cage to another. See text for more complete description of the apparatus. In the chart, each section between the numbered scales represents the record of a twenty-minute experiment, the distance between the scales representing the length of the cage, and the vertical length of the chart the time, twenty minutes, each division on the scale representing ten seconds. The curve in this space represents the movements of the animal under observation, and as the time-component is vertical and the space-component is horizontal, the parts of the curve more nearly horizontal represent the most rapid movements, while the vertical parts of the curve indicate that the animal was at rest during the length of time indicated on the scale. Thus, in chart 2a (the fourth from the left), the animal, introduced near the centre of the cage, remains in that position for approximately one minute, and then moves toward the left end of the cage, the movement occupying a period of ten seconds. The lizard remains in this position for a little over twenty seconds, and then moves toward the other end of the cage, where he arrives at the end of the second minute. Here he remains for three minutes, when he again moves toward the left end of the cage.

The figures accompanied by letters at the top of each section of the chart designate the number of the experiment. Experiments designated by the same number and consecutive letters were performed with the same animal and consecutively. Otherwise the experiment numbers are entirely arbitrary. The upper line of three figures in each section *e. g.*, 34, 19, 4, in 1*a*, indicates the relative humidity of the air passing through the corresponding thirds of the cage, as computed from standard wet and dry bulb thermometer readings. *SSS* in 1*c* and 5*c* indicates that in these control experiments the air was still and the same in all sections of the cage. The lower line of figures, *e. g.*, .5, .9, 1.5 in 1*a*, represents the standard atmometer reading, for a similar twenty-minute period, of the air passing through the corresponding third of the cage. Thus, in Experiment 1*a*, the relative humidity of the air passing through the left-hand third of the cage was 34 per cent., and the corresponding atmometer reading .5 c.c. In the middle third the relative humidity was 19 per cent. and the atmometer reading .9 c.c., while in the right-hand third the relative humidity was 4 per cent. and the atmometer reading correspondingly high, or 1.5 c.c. The rate at which the air passed across the cage was in each case 25 liters per sec.

Where the record is in the form of a dotted line, it indicates that the animal, in the corresponding period, either attempted to escape from the cage or to burrow in the sand on the cage bottom. In the records of experiments 3 and 4*a* the circles and the parallel lines following indicate that the animal burrowed under the sand and remained covered for the period indicated. In the record of experiment 5*a* the circle indicates that the animal was under the surface of the sand for a brief time only. For discussion of individual experiments see text.

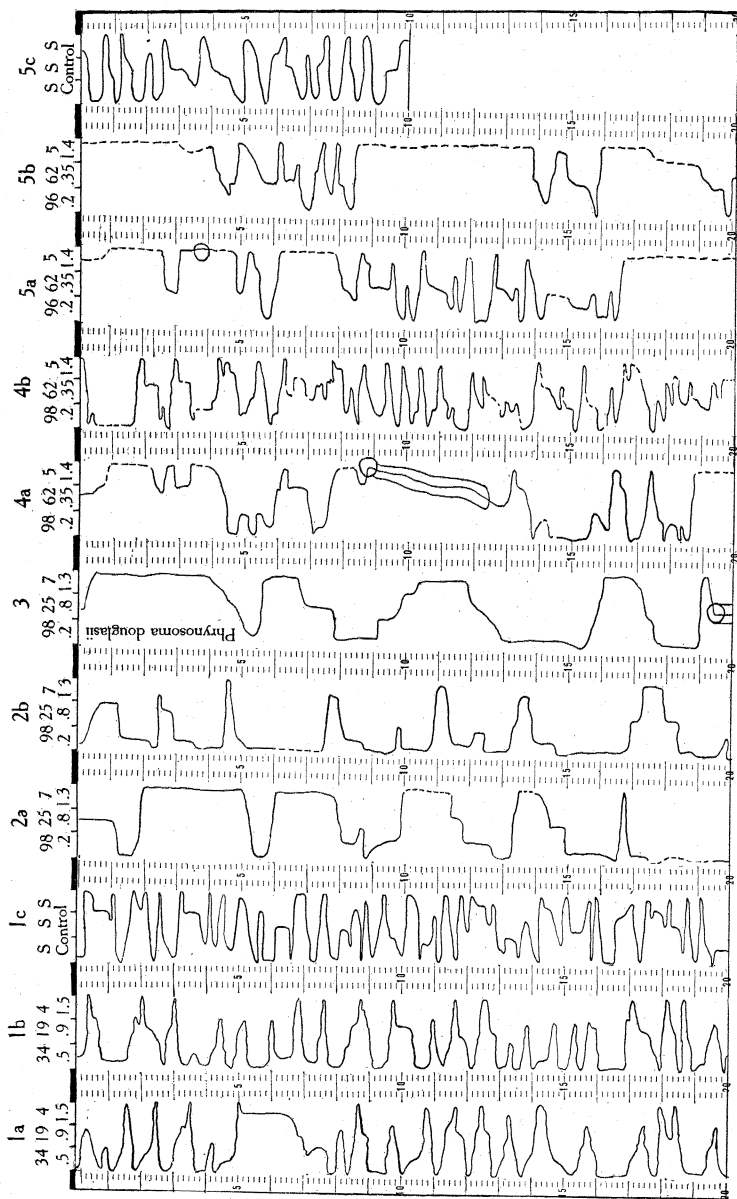
Experiments 1a, 1b, Control, 1c. (Chart I).—The tracing which is the graphic record of experiment 1*a* shows that the animal, for the first minute and a half, remained in the two portions of the cage where evaporation was lowest, then, at intervals about one minute made brief visits to the drier section. Following the fifth minute there is recorded a stay of over one minute in the driest third of the cage. Aside from this all the longer rest periods were spent in the opposite end of the cage. It will be noticed that, in general, the apices of the curves at the right are sharper than those at the left, indicating quicker turning in this region. In the first minute the animal turns away from the drier portion of the cage twice, once in the fifth minute, again in the eighth, tenth, sixteenth, eighteenth and twentieth minutes. There is only one turning back from the more moist regions, in the nineteenth minute.

The record of 1*b* is of almost the same character, with more avoidance of the dry end, as there are ten turnings during this twenty-minute period.

The control, 1*c*, in which the same animal was used shows somewhat greater activity than the two previous experiments, as the line crosses the area representing the cage a greater number of times. This curve, however, is not in the least one-sided, showing that the animal avoided no region of the cage. As indicated at the top of the chart, there was no air current through the cage in the control.

Experiments 2a, 2b.—In this experiment one end of the cage was supplied with air nearly "saturated" with moisture, as is indicated by the relative humidity of 98 per cent. and an atmometer reading of .2 c.c. During the first twenty-minute period, represented by tracing 2*a* the animal spent a little more time in the dry end than in the very moist region. During the second twenty-minute period (2*b*) the animal reached the dry third but six times, turning back almost immediately in

CHART I



each case. The longest stay in the dry end was in the eighteenth minute—about forty seconds.

Experiment 3.—This experiment is typical of those performed with *Phrynosoma douglasii*, and shows very little. The animal was inclined to be sluggish and finally, at the end of the period, burrowed in the middle section of the cage, where the humidity was 25 per cent. and the evaporation .8 c.c.

Experiments 4a, 4b.—This animal, beginning in the center section of the cage, moved, after nearly one minute, to the dry end, where attempts to escape, indicated by the dotted line, were recorded. It turned back from the medium section twice in the next two minutes, attempting to escape during the second stay in the dry section, and then spent nearly two minutes in the wet end, turning back twice from the medium air. A short visit to the dry end was then recorded, and then, at the beginning of the ninth minute, a marked escape reaction in the dry end, followed by a period of three and one half minutes, when the animal burrowed beneath the soil. While under the soil, the animal gradually moved toward the center of the cage and finally emerged there. Thereafter visits to the dry third were of very short duration until near the end of the period when escape at this end is again attempted. During the second period (4b) the animal was very active, and, except that, in general, the apices of the curves in the section of the diagram representing the dry end of the cage are more acute, indicating quicker turning here, very little can be said. There were many escape reactions in all parts of the cage.

Experiment 5a, 5b, Control 5c.—This experiment shows more definitely than any other the relation between stimulation to escape attempts and the length of stay in the dry air. It will be noted that escape attempts were recorded throughout each stay of any length in the dry air, and that, aside from these periods of stimulation the animal spent the greater part of the time in the center section of the cage. One short burrowing movement was recorded at the end of the fourth minute of the first period. The control, as elsewhere, showed a rather active movement from end to end of the cage, but no avoidance of any region.